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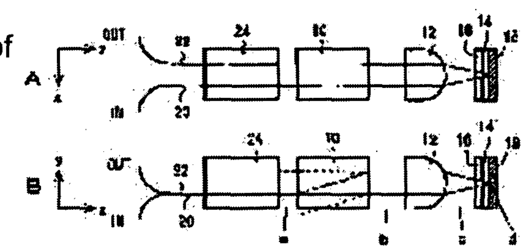
(54) VARIABLE OPTICAL ATTENUATOR

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a variable optical attenuator with a small number of components, that can easily be assembled because each optical component can easily be processed, can inexpensively be manufactured, downsized, designed independently of a polarized wave, and have an enhanced degree of freedom in mounting by placing input and output to the same side of the attenuator.



SOLUTION: In the variable optical attenuator, a parallel plane type splitting and compositing double refraction element 10 that splits lights whose polarized wave directions are orthogonal to the same optical paths and composites lights of the different optical paths, an optical converging lens (convex lens 12) and a reflection mirror 18 placed at a focal position of the lens are arranged in the order. Then a variable polarized wave rotation means (basic film Farady element 14) and a stationary polarized wave rotation means (basic film Farady element 16) are placed between the splitting and compositing double refraction element and the reflection mirror, an input port (input fiber 20) and an output port (output fiber 22) are placed at the side of the splitting and compositing double refraction

element. The variable polarized wave rotation means controls a rotary angle in a direction of a polarized wave to control a reflection output light quantity.

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CLAIMS

[Claim(s)]
[Claim 1] The parallel flat-surface type birefringence element for separation composition which compounds the light of the optical path from which the direction of polarization separates the light of the same optical path in orthogonality relation, and differs, The lens of optical convergency and the reflecting mirror arranged in the focal position of this lens are arranged in the sequence. An adjustable polarization rotation means is installed in the arbitrary positions between the aforementioned birefringence element for separation composition, and a reflecting mirror. The good light variation attenuator characterized by controlling the reflective output quantity of light by setting input port and an output port to the edge side of the aforementioned birefringence element for separation composition, and controlling angle of rotation of the direction of polarization by the aforementioned adjustable polarization rotation means.
[Claim 2] The good light variation attenuator according to claim 1 which installed 2 heart ferrule so that an input fiber might be located in input port and an output fiber might be located in an output port.
[Claim 3] The parallel flat-surface type birefringence element for separation composition which compounds the light of the optical path from which the direction of polarization separates the light of the same optical path in orthogonality relation, and differs, The lens of optical convergency and the reflecting mirror arranged in the focal position of this lens are arranged in the sequence. An adjustable polarization rotation means and a fixed polarization rotation means are installed in the arbitrary positions between the aforementioned birefringence element for separation composition, and a reflecting mirror. The good light variation attenuator characterized by controlling the reflective output quantity of light by setting input port and an output port to the edge side of the aforementioned birefringence element for separation composition, and controlling angle of rotation of the direction of polarization by the aforementioned adjustable polarization rotation means.
[Claim 4] The good light variation attenuator according to claim 3 which installed 2 heart ferrule so that an input fiber might be located in input port and an output fiber might be located in an output port.
[Claim 5] An adjustable polarization rotation means is a good light variation attenuator possessing the Faraday cell from which a Faraday-rotation angle changes according to an adjustable composition magnetic field, and the adjustable magnetic field impression means which impresses an external magnetic field to this Faraday cell more than from a 2-way, and carries out adjustable [of those synthetic magnetic fields] according to claim 1 or 2.
[Claim 6] The good light variation attenuator according to claim 3 or 4 characterized by providing the following. An adjustable polarization rotation means is a basic film Faraday cell from which a Faraday-rotation angle changes according to an adjustable composition magnetic field. A fixed polarization rotation means is a compensation film Faraday cell from which the magnetic field impression means which impresses an external magnetic field to this basic film Faraday cell more than from a 2-way, and carries out adjustable [of those synthetic magnetic fields] is provided, and, as for the aforementioned basic film Faraday cell, the direction of Faraday rotation differs. A magnetic field impression means to impress an external magnetic field to this compensation film Faraday cell from one or more directions.

[Claim 7] A compensation film Faraday cell is a good light variation attenuator according to claim 6 which is what presents the property that a Faraday-rotation angle hardly changes to an adjustable composition magnetic field.
[Claim 8] It is the maximum angle of rotation according the maximum angle of rotation by the basic film Faraday cell to theta 1 and a compensation film Faraday cell theta 2 Good light variation attenuator according to claim 6 or 7 which fills [in the case of theta1 <=61 degree] the relation it is unrelated 32-theta1 <=theta2 <=58-theta1 in the case of 32-theta1 <=theta2 <=-3theta1 >=61 degree when it carries out.
[Claim 9] The good light variation attenuator according to claim 1 to 8 which the parallel flat-surface type birefringence element for separation composition becomes from a rutile crystal.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] When this invention is described in more detail about a reflected type good light-variation attenuator, it arranges the birefringence element for separation composition, a lens, and a reflecting mirror, sets input port and an output port to the birefringence element side for separation composition, and relates to the good light-variation attenuator whose adjustment of the magnitude of attenuation of an incident light was enabled by controlling angle of rotation of the direction of polarization by the adjustable polarization rotation means installed between the birefringence element for separation composition, and the reflecting mirror.
[0002]
[Description of the Prior Art] The optical attenuator for controlling the amount of transmitted lights is required of an optical transmission system or an optical instrumentation system. Typically as this kind of an optical attenuator, the composition of the opposed type which installs a polarizer and an analyzer before and behind on the optical axis of Faraday-rotation angle adjustable equipment (an input side and output side) is adopted. The Faraday-rotation angle adjustable equipment incorporated impresses an external magnetic field to Faraday cells (magnetic garnet single crystal film which has the Faraday effect) with an electromagnet etc., and controls the Faraday-rotation angle of the beam of light which penetrates a Faraday cell by changing the external impression magnetic field. In an optical attenuator, adjustable control of the magnitude of attenuation of light is carried out by control of this Faraday-rotation angle.
[0003] In such an optical attenuator, as a polarizer and an analyzer, although a compound polarizing prism may be used theoretically, when a compound polarizing prism is used, the amount of incident lights will be mostly halved with a polarizer. Then, it is more practical to usually consider as polarization non-dependence in a fiber combination type device using a wedge birefringence crystal plate (for example, rutile crystal).
[0004] The incident light from an input fiber passes in order of a polarizer, the Faraday cell of Faraday-rotation angle adjustable equipment, and an analyzer, and is combined with an output fiber. A Faraday-rotation angle will change by controlling the adjustable magnetic field impressed to a Faraday cell, and the quantity of light which can pass an analyzer by it will be controlled.
[0005]
[Problem(s) to be Solved by the Invention] However, if the dimensional accuracy of the wedge birefringence crystal plate which makes a pair is very important for a polarizer and an analyzer in the optical attenuator of the structure which uses a wedge birefringence crystal plate and pair precision is bad, it will have a bad influence on an isolation property. Therefore, processing is very difficult and it takes cost and time. Furthermore, it sets like an assembler, and the precision of the alignment of the direction which intersects perpendicularly with the optical axis of a wedge birefringence crystal plate is important, and the position gap also has a bad influence on an isolation property. Therefore, much cost also starts assembly adjustment.

[0006] By the way, incorporating an optical attenuator for every wavelength for the equation of an insertion loss is performed by having begun to put wavelength multiplex communication in practical use in recent years. It is important that it can manufacture cheaply and can miniaturize especially with such a use gestalt. Use of a wedge birefringence crystal plate is disadvantageous at such a point.
[0007] Moreover, as for such a conventional optical attenuator, since light is the opposed type (composition in which an input fiber and an output fiber are located in the edge of an opposite side) which passes from the end side of a device to an other end side, except when carrying out opposite arrangement of the I/O, for fiber leading about, a latus space is needed and the flexibility of mounting also has a low problem. Furthermore, a big installation space is required for a direction perpendicular to an optical axis because of the electromagnet which is the component part of Faraday-rotation angle adjustable equipment, and there is also a problem whichis [thin-shape-] hard toize.
[0008] The purpose of this invention is offering the good light variation attenuator which there are few required part mark, and processing of each optic is easy, and can be easy to assemble, can manufacture cheaply, and can be miniaturized, and is moreover made to polarization non-dependence. Other purposes of this invention are setting I/O to the same device side, and the flexibility at the time of mounting is offering the good light variation attenuator suitable for increase and thin shape-ization.
[0009]
[Means for Solving the Problem] The parallel flat-surface type birefringence element for separation composition which compounds the light of an optical path which this invention separates the light of the same optical path which has the direction of polarization in orthogonality relation, and is different, The lens of optical convergency and the reflecting mirror arranged in the focal position of this lens are arranged in the sequence. An adjustable polarization rotation means is installed in the arbitrary positions between the aforementioned birefringence element for separation composition, and a reflecting mirror. It is the good light variation attenuator characterized by controlling the reflective output quantity of light by setting input port and an output port to the edge side of the aforementioned birefringence element for separation composition, and controlling angle of rotation of the direction of polarization by the adjustable polarization rotation means.
[0010] Moreover, the parallel flat-surface type birefringence element for separation composition which compounds the light of an optical path which this invention separates the light of the same optical path which has the direction of polarization in orthogonality relation, and is different, The lens of optical convergency and the reflecting mirror arranged in the focal position of this lens are arranged in the sequence. An adjustable polarization rotation means and a fixed polarization rotation means are installed in the arbitrary positions between the aforementioned birefringence element for separation composition, and a reflecting mirror. It is the good light variation attenuator characterized by controlling the reflective output quantity of light by setting input port and an output port to the edge side of the aforementioned birefringence element for separation composition, and controlling angle of rotation of the direction of polarization by the adjustable polarization rotation means.
[0011] Through the birefringence element for separation composition, and a lens, the light which carried out incidence condenses to a reflecting mirror, and is reflected, and outgoing radiation of the reflective return light is again carried out through a lens and the birefringence element for separation composition. Light goes and comes back to an adjustable polarization rotation means or an adjustable polarization rotation means, and a fixed polarization rotation means (in fact portion of those Faraday cells) in the process. As reflected type composition, it constitutes from this invention so that one birefringence element may make two functions, a polarizer and an analyzer, serve a double purpose, respectively.
[0012] Here, 2 heart ferrule is installed so that an input fiber may be located in input port and an output fiber may be located in an output port. Of course, it may replace with an optical fiber and an optical waveguide etc. may be used.
[0013] Typically, an adjustable polarization rotation means turns into an adjustable magnetic field impression means by which a magnetic field can be impressed from a 2-way and those synthetic magnetic fields can be changed from the basic film Faraday cell from which a Faraday-rotation angle changes according to the synthetic magnetic field. Moreover, typically, a fixed polarization rotation

means is not based on the synthetic magnetic field impressed, but has a compensation film Faraday cell with a fixed Faraday-rotation angle. The direction of Faraday rotation of a basic film Faraday cell and a compensation film Faraday cell chooses material so that it may become a retrose. Although it is desirable to share at least a part, you may constitute individually the magnetic field impression means of these adjustable polarization rotation means and a fixed polarization rotation means. It arranges combining a basic film Faraday cell and a compensation film Faraday cell, a fixed field system is impressed in the direction to which light goes with a permanent magnet etc., and an adjustable magnetic field is impressed in the direction perpendicular to it with an electromagnet etc. The high magnitude of attenuation is realizable by considering as such composition.

[0014] this invention is a reflected type, and when the basic film Faraday cell whose Faraday-rotation angle is 45 degrees is used, in order that light may go and come back to a Faraday cell, on the other hand, Mukai's Faraday-rotation angle will rotate 90 degrees both ways at least 45 degrees. Since the direction of a synthetic magnetic field does not become perpendicular to the direction to which light goes in impressing a synthetic magnetic field with a vertical adjustable magnetic field to the fixed field system of the direction of an optical axis, and it, the adjustable width of face of a Faraday-rotation angle will become about 5 - 90 degrees, and the adjustable width of face of the magnitude of attenuation will also become small. However, since the adjustable width of face of a Faraday-rotation angle becomes large with 0 - 90 degrees when a basic film Faraday cell and a compensation film Faraday cell are combined, the adjustable width of face of the magnitude of attenuation also becomes large.

[0015] As an parallel flat-surface type birefringence element for separation composition, a rutile crystal is used, for example. As for an "parallel flat-surface type", plane of incidence and an outgoing radiation side say an parallel configuration (plane of incidence does not need to be strictly perpendicular to an incident light), and not only an parallel monotonous configuration but a block configuration or a rectangular parallelepiped configuration of a parallelogram etc. is included here.

[0016]

[Example] Drawing 1 is optical-path explanatory drawing showing one example of the good light variation attenuator concerning this invention, and drawing 2 is explanatory drawing of the polarization situation between each of that optic. In order to give explanation intelligible, the following axes of coordinates are set up. The array direction (direction to which an incident light goes) of an optic is made into the direction (a drawing right) of z, and let the 2-ways which intersect perpendicularly to it be x directions (horizontal) and the direction (perpendicular direction) of y. Therefore, A of drawing 1 will call it a plan and B will call it front view. The polarization situation shown by a-d of drawing 2 is drawing seen in the direction to which the light in the position shown by a-d of B of drawing 1 goes.

[0017] At this good light-variation attenuator, the parallel flat-surface type birefringence element 10 for separation composition which compounds the light of a different optical path which separates the light of the same optical path which has the direction of polarization which goes in the direction of z in orthogonality relation in the direction of y, and goes in the direction of -z in the direction of -y, the convex lens 12, basic film Faraday cell 14 and compensation film Faraday cell 16, and the reflecting mirror 18 arranged in the focal position of the aforementioned convex lens 12 are arranged in the And input port and an output port are set as the side (a drawing left end side) of the aforementioned birefringence element 10 for separation composition. In this example, 2 heart ferrule 24 is installed so that the direction of z may be seen, the input fiber 20 may be located in the input port of a lower-berth right-hand side optical path and the output fiber 22 may be located in the output port of a lower-berth left-hand side optical path.

[0018] The birefringence element 10 for separation composition consists of an parallel monotonous type rutile crystal. By a Faraday-rotation angle not changing according to the synthetic magnetic field according [basic film Faraday cell 14] to the impression magnetic field from a 2-way, compensation film Faraday cell 16 is not based on a synthetic magnetic field, a Faraday-rotation angle maintains simultaneously regularity, and, as for a basic film Faraday cell, the directions of Faraday rotation differ. Although a magnetic field impression means omits illustrating, it is the composition of impressing a fixed field system in the direction to which light goes with a permanent magnet, and impressing an

adjustable magnetic field in the direction perpendicular to it with an electromagnet. Here, it considers as arrangement to which both these fixed field systems and an adjustable magnetic field are impressed to a basic film Faraday cell and a compensation film Faraday cell.

[0019] Next, operation of this good light variation attenuator is explained.

[0020] (Faraday-rotation angle : 45 degrees) The case where the Faraday-rotation angle of the sum total by basic film Faraday cell 14 and compensation film Faraday cell 16 is 45 degrees is first shown in A of drawing 2 . In the light which carries out incidence in the direction of z from the input fiber 20, Tsunemitsu goes straight on with the birefringence element 10 for separation composition, and unusual light is refracted and carries out optical separation in the direction of y. And it condenses with a convex lens 12 and compensation film Faraday cell 16 and basic film Faraday cell 14 are passed by the middle. Since the Faraday-rotation angle is set as 45 degrees, the direction of polarization rotates 45 degrees, and reaches and reflects in the reflecting mirror 18 of a lens focal position. - The reflected light which returns in the direction of z passes basic film Faraday cell 14 and compensation film Faraday cell 16 again, and in that case, the direction of polarization carries out rotation of it further 45 degrees (therefore, the sum total 90 degrees), and it turns into parallel light with a convex lens 12. Tsunemitsu of a lower-berth optical path goes straight on with the birefringence element 10 for separation composition, since the unusual light of an upper case optical path is refracted in the direction of -y, polarization composition is carried out and all light combines it with the output fiber 22. Thus, when a Faraday-rotation angle is 45 degrees, the total quantity of light will carry out outgoing radiation of most amounts of incident lights from the input fiber 20 to the output fiber 22 mostly, without decreasing.

[0021] (Faraday-rotation angle : 0 times) Next, the case where the Faraday-rotation angle of the sum total by basic film Faraday cell 14 and compensation film Faraday cell 16 is 0 times is shown in C of drawing 2 . In the light which carries out incidence in the direction of z from the input fiber 20, Tsunemitsu goes straight on with the birefringence element 10 for separation composition, and unusual light is refracted and carries out optical separation in the direction of y. And it condenses with a convex lens 12 and compensation film Faraday cell 16 and basic film Faraday cell 14 are passed by the middle. Since the Faraday-rotation angle is set as 0 times, it does not rotate, but the direction of polarization is attained and reflected in the reflecting mirror 18 of a lens focal position. - Although the reflected light which returns in the direction of z passes basic film Faraday cell 14 and compensation film Faraday cell 16 again, don't rotate the direction of polarization in that case, either, but it becomes parallel light with a convex lens 12. And with the birefringence element 10 for separation composition, Tsunemitsu of an upper case optical path goes straight on, and the unusual light of a lower-berth optical path is refracted in the direction of -y. Therefore, the incident light from the input fiber 20 is hardly combined with the output fiber 22. that is, the amount of incident lights from an input fiber -- all will decrease almost

[0022] (Faraday-rotation angle : 22.5 degrees) It is as follows when it is arbitrary angles while the Faraday-rotation angle of the sum total by basic film Faraday cell 14 and compensation film Faraday cell 16 is 0 - 45 degrees. For example, the time of 22.5 degrees is shown in B of drawing 2 . In the light which carries out incidence in the direction of z from the input fiber 20, Tsunemitsu goes straight on with the birefringence element 10 for separation composition, and unusual light is refracted and carries out optical separation in the direction of y. And it condenses with a convex lens 12 and compensation film Faraday cell 16 and basic film Faraday cell 14 are passed by the middle. By compensation film Faraday cell 16 and basic film Faraday cell 14, arbitration carries out angle (B of drawing 2 22.5 degrees) rotation, and the direction of polarization is attained and reflected in the reflecting mirror 18 of a lens focal position. - the reflected light which returns in the direction of z passes basic film Faraday cell 14 and compensation film Faraday cell 16 again, and its direction of polarization is still the same also in that case -- carry out angle (here, it is 45 degrees by 22.5 degree:, therefore the sum total) rotation, and it becomes parallel light with a convex lens 12 And since the amount of [of a lower-berth optical path] usual state Mitsunari goes straight on with the birefringence element 10 for separation composition and the unusual light component of an upper case optical path is refracted in the direction of -y, polarization composition is carried out and those components are combined with the output fiber 22. However, since the amount of [of an upper case optical path] usual state Mitsunari goes straight on

and the unusual light component of a lower-berth optical path is refracted in the direction of -y, these components are not combined with an output fiber. Therefore, the incident light from the input fiber 20 will decline, and will carry out outgoing radiation to the output (amount of incident lights mostly halved, when Faraday-rotation angle is set as 22.5 degrees) fiber 22.
[0023] Thus, the magnitude of attenuation (if it puts in another way reflective output quantity of light) of an incident light can be freely adjusted by controlling angle of rotation of the direction of polarization by basic film Faraday cell 14.
[0024] The electromagnet magnetic field strength when using only a basic film Faraday cell 45 degrees and the relation of a Faraday-rotation angle are shown in drawing 3 , and the relation between electromagnet magnetic field strength and a magnitude-of-attenuation property is shown in drawing 4 . Although it functions as a good light variation attenuator even when only a basic film Faraday cell is used 45 degrees, since the adjustable width of face of a Faraday-rotation angle becomes about 8 - 90 degrees on the capacity of an electromagnet (in order that a synthetic magnetic field may not turn to an optical axis perpendicularly completely), the maximum magnitude of attenuation is set to about 15dB.
[0025] The electromagnet magnetic field strength when combining a basic film Faraday cell and a -10-degree compensation film Faraday cell 55 degrees to it and the relation of a Faraday-rotation angle are shown in drawing 5 , and the relation between electromagnet magnetic field strength and a magnitude-of-attenuation property is shown in drawing 6 . here -- a basic film Faraday cell -- for example, Tb1.00Y0.65Bi1.35Fe4.05Ga 0.95O12 -- the magnetic garnet LPE film of composition -- it is -- a compensation film Faraday cell -- for example, Gd1.00Y0.75Bi1.25Fe4.00Ga 1.00O12 -- it is the magnetic garnet LPE film of composition If it is made such a combination, the adjustable width of face of a Faraday-rotation angle will become large with -10 - 90 degrees, and can also enlarge the maximum magnitude of attenuation to about 40dB.
[0026] As mentioned above, although one example of this invention was explained, this invention is not limited only to this composition. The insertion point of a basic film Faraday cell and a compensation film Faraday cell is not restricted to the example of drawing 1 . Drawing 7 shows other examples. In order to simplify explanation, the same sign is attached about drawing 1 and an optic.
[0027] In the example shown in A of drawing 7 , basic film Faraday cell 14 and compensation film Faraday cell 16 are arranged between the birefringence element 10 for separation composition, and a lens 12. Although the same is said of the case of drawing 1 , reverse is sufficient as the sequence of basic film Faraday cell 14 and compensation film Faraday cell 16. In the example shown in B of drawing 7 , basic film Faraday cell 14 is arranged between a lens 12 and a reflecting mirror 18, and compensation film Faraday cell 16 is arranged between the birefringence element 10 for separation composition, and a lens 12. In the example shown in C of drawing 7 , conversely, basic film Faraday cell 14 is arranged between the birefringence element 10 for separation composition, and a lens 12, and compensation film Faraday cell 16 is arranged between a lens 12 and a reflecting mirror 18.
[0028] Even when a basic film Faraday cell and a compensation film Faraday cell attain to plurality, as long as it is between the birefringence element 10 for separation composition, and a reflecting mirror 18, you may arrange in any position. For example, in the example shown in D of drawing 7 , the basic film Faraday cell of two sheets and the compensation film Faraday cell of one sheet are arranged between a lens 12 and a reflecting mirror 18 in piles in order of basic film Faraday cell 14, compensation film Faraday cell 16, and basic film Faraday cell 14.
[0029] The result which investigated the relation between the basic film angle of rotation from which the insertion loss in the electromagnet magnetic field strength 0 is set to 1dB or less, and a compensation film angle of rotation is shown in Table 1. Moreover, if it is within the limits shown in Table 1 when a basic film angle of rotation is 61 or less degrees and a compensation film angle of rotation is [-3 or less times and a basic film angle of rotation] 61 degrees or more, the high magnitude of attenuation 25dB or more can be obtained.
[0030]
[Table 1]

基本膜最大回転角θ_1（度）	補償膜最大回転角θ_2（度）
40	$\theta_2 \geqq -8$
42	$\theta_2 \geqq -10$
44	$\theta_2 \geqq -12$
46	$\theta_2 \geqq -14$
48	$\theta_2 \geqq -16$
50	$\theta_2 \geqq -18$
52	$\theta_2 \geqq -20$
54	$\theta_2 \geqq -22$
56	$\theta_2 \geqq -24$
58	$\theta_2 \geqq -26$
60	$\theta_2 \geqq -28$
61	$-29 \leqq \theta_2 \leqq -3$
62	$-30 \leqq \theta_2 \leqq -4$
64	$-32 \leqq \theta_2 \leqq -6$
66	$-34 \leqq \theta_2 \leqq -8$
68	$-36 \leqq \theta_2 \leqq -9$
70	$-38 \leqq \theta_2 \leqq -11$
72	$-40 \leqq \theta_2 \leqq -13$
74	$-42 \leqq \theta_2 \leqq -15$
76	$-44 \leqq \theta_2 \leqq -17$
78	$-46 \leqq \theta_2 \leqq -19$
80	$-48 \leqq \theta_2 \leqq -21$
82	$-50 \leqq \theta_2 \leqq -23$
84	$-52 \leqq \theta_2 \leqq -25$
86	$-54 \leqq \theta_2 \leqq -27$
88	$-56 \leqq \theta_2 \leqq -29$
90	$-58 \leqq \theta_2 \leqq -31$

[0031] The insertion loss in the electromagnet magnetic field strength 0 is small, and the field shown with the slash of drawing 8 showed the relation of the Faraday-rotation angle of the basic film Faraday cell which can obtain the high magnitude of attenuation, and a compensation film Faraday cell. When a formula shows, it is the maximum angle of rotation according the maximum angle of rotation by the basic film Faraday cell to theta 1 and a compensation film Faraday cell theta 2 When it carries out, in the case of theta1 <=61 degree, in the case of 32-theta1 <=theta2 <=-3theta1 >=61 degree, it is desirable to make it fill the relation it is unrelated 32-theta1 <=theta2 <=58-theta1.

[0032] Specifically, a fixed-field-system impression means is constituted from arranging the permanent magnet in a circle magnetized to shaft orientations on an optical axis, and an adjustable magnetic field impression means is considered as composition in which a basic film Faraday cell is located in the gap as an electromagnet which looped the C type core around the coil. It is a reflected type, and since an optical path does not exist in the rear-face side of a reflecting mirror, it is arranging an electromagnet using the space of the background of the reflecting mirror, and it is [the superficial part arrangement of this invention is attained, and] effective in thin-shape-izing of a good light variation attenuator.

[0033]

[Effect of the Invention] Since this invention is the reflected type good light variation attenuator constituted as mentioned above, though part mark are a ** space few, an equivalent performance may be discovered as compared with the optical attenuator of the conventional opposed type. Moreover, the structure to which the good light variation attenuator concerning this invention was suitable also for the increase of the flexibility of mounting and thin shape-ization since input port and an output port served as the same direction is acquired. Furthermore, since there are few part mark, it becomes possible to manufacture by the low price.

[0034] Moreover, by this invention, in order that light may pass both ways, in the case of the conventional opposed type, the thickness of a Faraday cell is compared, and can be reduced by half, and-izing can be carried out [low cost] also at the point. Furthermore, if it is the composition which combines a basic film Faraday cell and a compensation film Faraday cell, the adjustable width of face of a Faraday-rotation angle will become large, the maximum magnitude of attenuation can be enlarged to about 40dB, and a good property will be acquired.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Optical-path explanatory drawing showing one example of the good light variation attenuator concerning this invention.
[Drawing 2] Explanatory drawing of the polarization situation between each of that optic.
[Drawing 3] The graph which shows the electromagnet magnetic field strength when using only a basic film Faraday cell 45 degrees, and the relation of a Faraday-rotation angle.
[Drawing 4] The graph which shows the electromagnet magnetic field strength when using only a basic film Faraday cell 45 degrees, and the relation of a damping property.
[Drawing 5] The graph which shows the electromagnet magnetic field strength when combining a basic film Faraday cell and a -10-degree compensation film Faraday cell 55 degrees, and the relation of a Faraday-rotation angle.
[Drawing 6] The graph which shows the electromagnet magnetic field strength when combining a basic film Faraday cell and a -10-degree compensation film Faraday cell 55 degrees, and the relation of a damping property.
[Drawing 7] Optical-path explanatory drawing showing other examples of the good light variation attenuator concerning this invention.
[Drawing 8] Explanatory drawing showing the relation of the Faraday-rotation angle of a basic film Faraday cell and a compensation film Faraday cell whose insertion loss in the electromagnet magnetic field strength 0 can obtain the high magnitude of attenuation small.
[Description of Notations]
10 Birefringence Element for Separation Composition
12 Convex Lens
14 Basic Film Faraday Cell
16 Compensation Film Faraday Cell
18 Reflecting Mirror
20 Input Fiber
22 Output Fiber
24 2 Heart Ferrule

[Translation done.]

* NOTICES *

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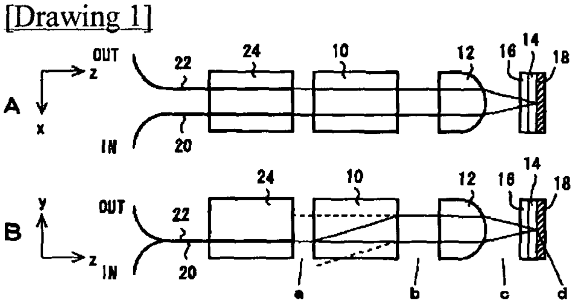
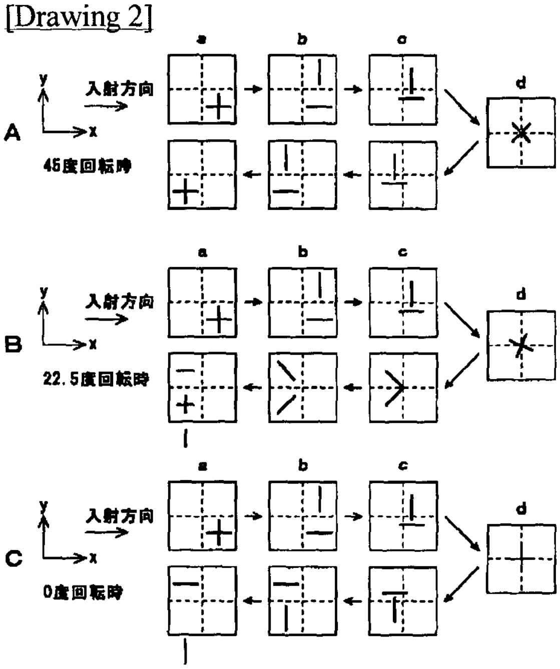
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

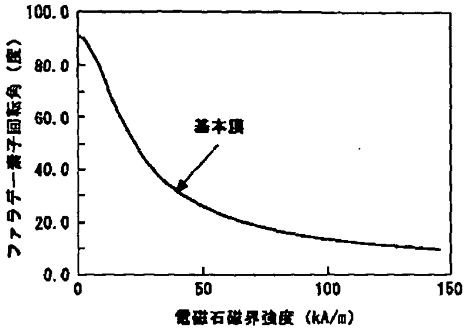
[Drawing 1]



[Drawing 2]



[Drawing 3]



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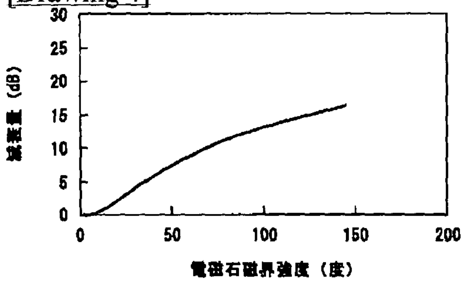

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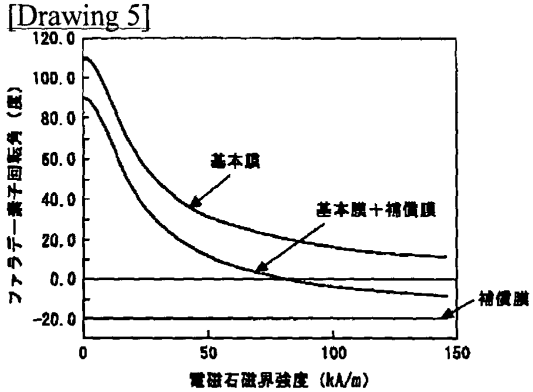

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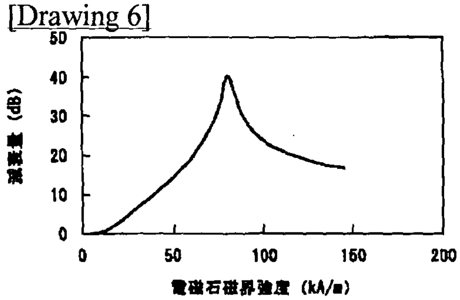

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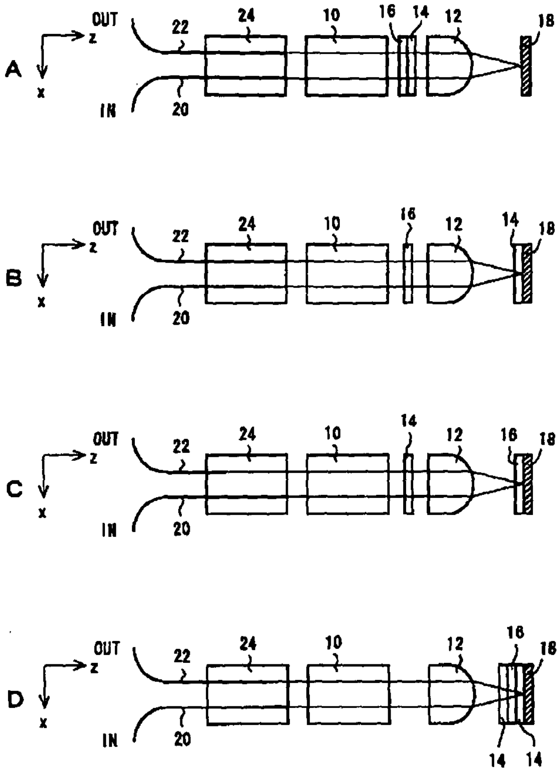
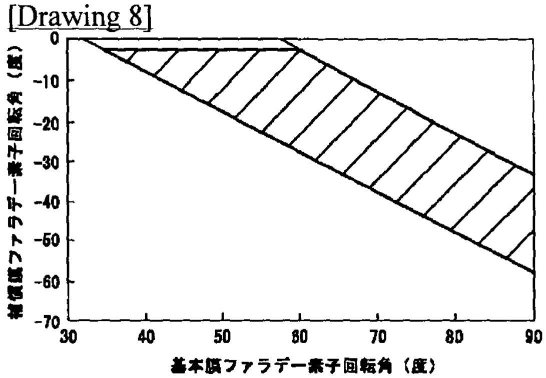


[Drawing 8]



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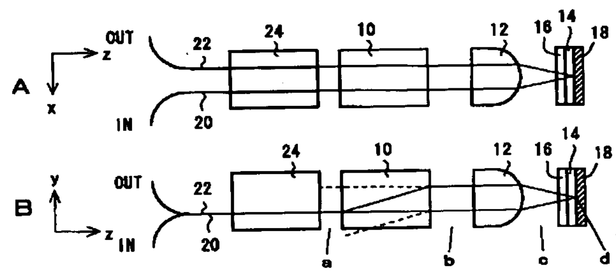
最終頁に続く

(54)【発明の名称】　可変光アッテネータ

(57)【要約】
【課題】　部品点数が少なく、各光学部品の加工が容易で組み立て易く、そのため安価に製作でき、小型化できるようにし、しかも偏波無依存型とする。入出力をデバイスの同じ側に設定することで、実装時の自由度が増すようにする。
【解決手段】　偏波方向が直交関係にある同じ光路の光を分離し異なる光路の光を合成する平行平面型の分離合成用複屈折素子１０と、光収束性のレンズ（凸レンズ１２）と、該レンズの焦点位置に配置した反射鏡１８とをその順序で配列する。そして、分離合成用複屈折素子と反射鏡との間に、可変偏波回転手段（基本膜ファラデー素子１４）及び固定偏波回転手段（補償膜ファラデー素子１６）を設置し、分離合成用複屈折素子の側に入力ポート（入力ファイバ２０）と出力ポート（出力ファイバ２２）を設定する。可変偏波回転手段で偏波方向の回転角度を制御することにより反射出力光量を制御する。



【特許請求の範囲】

【請求項１】　偏波方向が直交関係にある同じ光路の光を分離し異なる光路の光を合成する平行平面型の分離合成用複屈折素子と、光収束性のレンズと、該レンズの焦点位置に配置した反射鏡とがその順序で配列され、前記分離合成用複屈折素子と反射鏡の間の任意の位置に可変偏波回転手段を設置し、前記分離合成用複屈折素子の端部側に入力ポートと出力ポートを設定し、前記可変偏波回転手段で偏波方向の回転角度を制御することにより反射出力光量を制御することを特徴とする可変光アッテネータ。

【請求項２】　入力ポートに入力ファイバが位置し、出力ポートに出力ファイバが位置するように、２芯フェルールを設置した請求項１記載の可変光アッテネータ。

【請求項３】　偏波方向が直交関係にある同じ光路の光を分離し異なる光路の光を合成する平行平面型の分離合成用複屈折素子と、光収束性のレンズと、該レンズの焦点位置に配置した反射鏡とがその順序で配列され、前記分離合成用複屈折素子と反射鏡の間の任意の位置に可変偏波回転手段と固定偏波回転手段を設置し、前記分離合成用複屈折素子の端部側に入力ポートと出力ポートを設定し、前記可変偏波回転手段で偏波方向の回転角度を制御することにより反射出力光量を制御することを特徴とする可変光アッテネータ。

【請求項４】　入力ポートに入力ファイバが位置し、出力ポートに出力ファイバが位置するように、２芯フェルールを設置した請求項３記載の可変光アッテネータ。

【請求項５】　可変偏波回転手段は、可変合成磁界に応じてファラデー回転角が変化するファラデー素子と、該ファラデー素子に２方向以上から外部磁界を印加してそれらの合成磁界を可変する可変磁界印加手段とを具備している請求項１又は２に記載の可変光アッテネータ。

【請求項６】　可変偏波回転手段は、可変合成磁界に応じてファラデー回転角が変化する基本膜ファラデー素子と、該基本膜ファラデー素子に２方向以上から外部磁界を印加してそれらの合成磁界を可変する磁界印加手段を具備し、固定偏波回転手段は、前記基本膜ファラデー素子とはファラデー回転方向が異なる補償膜ファラデー素子と、該補償膜ファラデー素子に１方向以上から外部磁界を印加する磁界印加手段を具備している請求項３又は４記載の可変光アッテネータ。

【請求項７】　補償膜ファラデー素子は、可変合成磁界に対して殆どファラデー回転角が変化しない特性を呈するものである請求項６記載の可変光アッテネータ。

【請求項８】　基本膜ファラデー素子による最大回転角をθ_1、補償膜ファラデー素子による最大回転角をθ_2としたとき、$\theta_1 \leqq 61$度の場合、

$32-\theta_1 \leqq \theta_2 \leqq -3$

$\theta_1 \geqq 61$度の場合、

$32-\theta_1 \leqq \theta_2 \leqq 58-\theta_1$

なる関係を満たす請求項６又は７記載の可変光アッテネータ。

【請求項９】　平行平面型の分離合成用複屈折素子がルチル結晶からなる請求項１乃至８のいずれかに記載の可変光アッテネータ。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、反射型の可変光アッテネータに関し、更に詳しく述べると、分離合成用複屈折素子と、レンズと、反射鏡を配列し、入力ポートと出力ポートを分離合成用複屈折素子の側に設定して、分離合成用複屈折素子と反射鏡との間に設置した可変偏波回転手段で偏波方向の回転角度を制御することにより入射光の減衰量を調整可能とした可変光アッテネータに関するものである。

【０００２】

【従来の技術】光通信システムあるいは光計測システムなどでは、透過光量を制御するための光アッテネータが必要である。この種の光アッテネータとしては、典型的には、ファラデー回転角可変装置の光軸上の前後（入力側と出力側）に偏光子と検光子とを設置する対向型の構成が採用されている。組み込まれているファラデー回転角可変装置は、ファラデー素子（ファラデー効果を有する磁性ガーネット単結晶膜など）に電磁石などにより外部磁界を印加し、その外部印加磁界を変化させることにより、ファラデー素子を透過する光線のファラデー回転角を制御するものである。光アッテネータでは、このファラデー回転角の制御によって、光の減衰量を可変制御する。

【０００３】このような光アッテネータにおいて、偏光子及び検光子として、原理的には複合偏光プリズムを用いてもよいが、複合偏光プリズムを用いると入射光量が偏光子によってほぼ半減することになる。そこで、ファイバ結合型デバイスでは、通常、楔形複屈折結晶板（例えばルチル結晶）を用いて偏波無依存型とする方が実際的である。

【０００４】入力ファイバからの入射光は、偏光子、ファラデー回転角可変装置のファラデー素子、検光子の順に通過し、出力ファイバに結合する。ファラデー素子に印加する可変磁界を制御することでファラデー回転角が変化し、それによって検光子を通過できる光量が制御されることになる。

【０００５】

【発明が解決しようとする課題】しかし、偏光子と検光子に楔形複屈折結晶板を使用する構造の光アッテネータでは、対をなす楔形複屈折結晶板の寸法精度が極めて重要であり、ペア精度が悪いとアイソレーション特性に悪影響を及ぼす。そのため、加工が非常に難しく、コストと時間がかかる。更に、組み立て工程においては、楔形複屈折結晶板の光軸に直交する方向の位置合わせの精度

が重要であり、その位置ずれもアイソレーション特性に悪影響を及ぼす。そのため、組み立て調整にも多くのコストがかかる。

【０００６】ところで近年、波長多重通信が実用化され始めたことにより、挿入損失の均等化のために各波長毎に光アッテネータを組み込むことが行われている。そのような使用形態では、特に安価に製作でき、小型化できることが重要である。楔形複屈折結晶板の使用は、このような点では不利である。

【０００７】また、このような従来の光アッテネータは、光がデバイスの一端側から他端側へと通過する対向型（入力ファイバと出力ファイバが反対側の端部に位置する構成）であるため、入出力を対向配置する場合以外はファイバ引き回しのために広いスペースが必要となり実装の自由度が低い問題もある。更に、ファラデー回転角可変装置の構成部品である電磁石のために、光軸に垂直な方向に大きな設置スペースが必要であり、薄型化し難い問題もある。

【０００８】本発明の目的は、必要な部品点数が少なく、各光学部品の加工が容易で、組み立て易く、そのため安価に製作でき、また小型化でき、しかも偏波無依存型にできる可変光アッテネータを提供することである。本発明の他の目的は、入出力をデバイスの同じ側に設定することで、実装時の自由度が増し、薄型化に適した可変光アッテネータを提供することである。

【０００９】

【課題を解決するための手段】本発明は、偏波方向が直交関係にある同じ光路の光を分離し異なる光路の光を合成する平行平面型の分離合成用複屈折素子と、光収束性のレンズと、該レンズの焦点位置に配置した反射鏡とがその順序で配列され、前記分離合成用複屈折素子と反射鏡の間の任意の位置に可変偏波回転手段を設置し、前記分離合成用複屈折素子の端部側に入力ポートと出力ポートを設定し、可変偏波回転手段で偏波方向の回転角度を制御することにより反射出力光量を制御することを特徴とする可変光アッテネータである。

【００１０】また本発明は、偏波方向が直交関係にある同じ光路の光を分離し異なる光路の光を合成する平行平面型の分離合成用複屈折素子と、光収束性のレンズと、該レンズの焦点位置に配置した反射鏡とがその順序で配列され、前記分離合成用複屈折素子と反射鏡の間の任意の位置に可変偏波回転手段と固定偏波回転手段を設置し、前記分離合成用複屈折素子の端部側に入力ポートと出力ポートを設定し、可変偏波回転手段で偏波方向の回転角度を制御することにより反射出力光量を制御することを特徴とする可変光アッテネータである。

【００１１】入射した光は、分離合成用複屈折素子、レンズを通って反射鏡に集光して反射され、反射戻り光は、再びレンズ、分離合成用複屈折素子を通って出射する。その過程で、光は、可変偏波回転手段、又は可変偏波回転手段と固定偏波回転手段（実際にはそれらのファラデー素子の部分）を往復する。本発明では反射型の構成として、１個の複屈折素子がそれぞれ偏光子と検光子の２つの機能を兼用するように構成しているのである。

【００１２】ここで、例えば入力ポートに入力ファイバが位置し、出力ポートに出力ファイバが位置するように、２芯フェルールを設置する。勿論、光ファイバに代えて光導波路などを用いてもよい。

【００１３】可変偏波回転手段は、典型的には、２方向から磁界を印加しそれらの合成磁界を変化させることができる可変磁界印加手段と、その合成磁界に応じてファラデー回転角が変化する基本膜ファラデー素子からなる。また固定偏波回転手段は、典型的には、印加される合成磁界によらずファラデー回転角が一定である補償膜ファラデー素子を有する。基本膜ファラデー素子と補償膜ファラデー素子のファラデー回転方向は逆向きとなるように材料を選択する。これら可変偏波回転手段と固定偏波回転手段の磁界印加手段は、少なくとも一部を共用するのが好ましいが、個別に構成してもよい。基本膜ファラデー素子と補償膜ファラデー素子を組み合わせて配置し、光が進む方向に永久磁石などにより固定磁界を印加し、それに垂直な方向に電磁石などによって可変磁界を印加する。このような構成とすることで高減衰量を実現できる。

【００１４】ファラデー回転角が４５度の基本膜ファラデー素子を用いた場合、本発明は反射型であり光がファラデー素子を往復するために、一方向のファラデー回転角が４５度でも往復で９０度回転することになる。光軸方向の固定磁界とそれに垂直方向の可変磁界との合成磁界を印加する場合には、合成磁界方向は光が進む方向に対して垂直にならないため、ファラデー回転角の可変幅は５～９０度程度となり、減衰量の可変幅も小さくなってしまう。しかし、基本膜ファラデー素子と補償膜ファラデー素子を組み合わせた場合には、ファラデー回転角の可変幅が０～９０度と大きくなるため、減衰量の可変幅も大きくなる。

【００１５】平行平面型の分離合成用複屈折素子としては、例えばルチル結晶を用いる。ここで「平行平面型」とは、入射面と出射面が平行である形状（入射面が入射光に対して厳密に垂直である必要はない）をいい、平行平板形状のみならず平行四辺形のブロック形状あるいは直方体形状なども含まれる。

【００１６】

【実施例】図１は本発明に係る可変光アッテネータの一実施例を示す光路説明図であり、図２はその各光学部品間での偏波状況の説明図である。説明を分かり易くするために、次のような座標軸を設定する。光学部品の配列方向（入射光が進む方向）をｚ方向（図面では右方向）とし、それに対して直交する２方向をｘ方向（水平方向）、ｙ方向（垂直方向）とする。従って、図１のＡは

平面図、Ｂは正面図ということになる。図２のａ～ｄで示す偏波状況は、図１のＢのａ～ｄで示す位置での光が進む方向に見た図である。

【００１７】この可変光アッテネータでは、ｚ方向に向かう偏波方向が直交関係にある同じ光路の光をｙ方向に分離し－ｚ方向に向かう異なる光路の光を－ｙ方向で合成する平行平面型の分離合成用複屈折素子１０と、凸レンズ１２と、基本膜ファラデー素子１４及び補償膜ファラデー素子１６と、前記凸レンズ１２の焦点位置に配置した反射鏡１８とが、その順序で配列されている。そして、前記分離合成用複屈折素子１０の側面（図面では左端の側面）に入力ポートと出力ポートを設定する。この実施例では、ｚ方向を見て下段右側光路の入力ポートに入力ファイバ２０が位置し、下段左側光路の出力ポートに出力ファイバ２２が位置するように、２芯フェルール２４を設置している。

【００１８】分離合成用複屈折素子１０は、平行平板型のルチル結晶からなる。基本膜ファラデー素子１４は、２方向からの印加磁界による合成磁界に応じてファラデー回転角が変化するものであり、補償膜ファラデー素子１６は、合成磁界によらずファラデー回転角がほぼ一定を保ち且つ基本膜ファラデー素子とはファラデー回転方向が異なるものである。磁界印加手段は、図示するのを省略するが、光が進む方向に永久磁石により固定磁界を印加し、それに垂直な方向に電磁石によって可変磁界を印加する構成である。ここでは、これら固定磁界と可変磁界の両方が基本膜ファラデー素子と補償膜ファラデー素子に印加されるような配置とする。

【００１９】次に、この可変光アッテネータの動作について説明する。

【００２０】（ファラデー回転角：４５度）まず、基本膜ファラデー素子１４と補償膜ファラデー素子１６とによる合計のファラデー回転角が４５度の場合を図２のＡに示す。入力ファイバ２０からｚ方向に入射する光は、分離合成用複屈折素子１０で常光は直進し、異常光は屈折してｙ方向に光分離する。そして凸レンズ１２で集光し、その途中で補償膜ファラデー素子１６及び基本膜ファラデー素子１４を通過する。ファラデー回転角が４５度に設定されているので、偏波方向が４５度回転し、レンズ焦点位置の反射鏡１８に達して反射する。－ｚ方向に戻る反射光は、再び基本膜ファラデー素子１４及び補償膜ファラデー素子１６を通過し、その際に偏波方向が更に４５度（従って合計で９０度）回転し、凸レンズ１２で平行光になる。分離合成用複屈折素子１０で下段光路の常光は直進し、上段光路の異常光は－ｙ方向に屈折するため、すべての光が偏波合成され出力ファイバ２２に結合する。このようにして、ファラデー回転角が４５度の場合は、入力ファイバ２０からの入射光量は、殆ど減衰することなくほぼ全光量が出力ファイバ２２へと出射することになる。

【００２１】（ファラデー回転角：０度）次に、基本膜ファラデー素子１４と補償膜ファラデー素子１６とによる合計のファラデー回転角が０度の場合を図２のＣに示す。入力ファイバ２０からｚ方向に入射する光は、分離合成用複屈折素子１０で常光は直進し、異常光は屈折してｙ方向に光分離する。そして凸レンズ１２で集光し、その途中で補償膜ファラデー素子１６及び基本膜ファラデー素子１４を通過する。ファラデー回転角が０度に設定されているので、偏波方向は回転せず、レンズ焦点位置の反射鏡１８に達し反射する。－ｚ方向に戻る反射光は、再び基本膜ファラデー素子１４及び補償膜ファラデー素子１６を通過するが、その際も偏波方向は回転せず、凸レンズ１２で平行光になる。そして、分離合成用複屈折素子１０で、上段光路の常光は直進し、下段光路の異常光は－ｙ方向に屈折する。従って、入力ファイバ２０からの入射光は、殆ど出力ファイバ２２には結合しない。つまり、入力ファイバからの入射光量の殆ど全てが減衰することになる。

【００２２】（ファラデー回転角：２２．５度）基本膜ファラデー素子１４と補償膜ファラデー素子１６とによる合計のファラデー回転角が０～４５度の間の任意の角度の時は、次のようになる。例えば２２．５度の時を図２のＢに示す。入力ファイバ２０からｚ方向に入射する光は、分離合成用複屈折素子１０で常光は直進し、異常光は屈折してｙ方向に光分離する。そして凸レンズ１２で集光し、その途中で補償膜ファラデー素子１６及び基本膜ファラデー素子１４を通過する。偏波方向は、補償膜ファラデー素子１６及び基本膜ファラデー素子１４とによって任意の角度（図２のＢでは２２．５度）回転し、レンズ焦点位置の反射鏡１８に達して反射する。－ｚ方向に戻る反射光は、再び基本膜ファラデー素子１４及び補償膜ファラデー素子１６を通過し、その際にも偏波方向が更に同じ角度（ここでは２２．５度：従って合計で４５度）回転し、凸レンズ１２で平行光になる。そして分離合成用複屈折素子１０で下段光路の常光成分は直進し、上段光路の異常光成分は－ｙ方向に屈折するため、それらの成分は偏波合成されて出力ファイバ２２に結合する。しかし、上段光路の常光成分は直進し、下段光路の異常光成分は－ｙ方向に屈折するため、これらの成分は出力ファイバには結合しない。従って、入力ファイバ２０からの入射光は減衰して（ファラデー回転角を２２．５度に設定した場合は、入射光量がほぼ半減して）出力ファイバ２２へと出射することになる。

【００２３】このようにして、基本膜ファラデー素子１４で偏波方向の回転角度を制御することによって、入射光の減衰量（言い換えれば反射出力光量）を自由に調整できることになる。

【００２４】４５度基本膜ファラデー素子のみを用いた時の電磁石磁界強度とファラデー回転角の関係を図３に、また電磁石磁界強度と減衰量特性の関係を図４に示

す。４５度基本膜ファラデー素子のみを用いた場合でも可変光アッテネータとして機能するが、ファラデー回転角の可変幅が、電磁石の能力上（合成磁界が完全に光軸に垂直方向を向かないため）８～９０度程度になるため、最大減衰量は１５ｄＢ程度になる。

【００２５】それに対して５５度基本膜ファラデー素子と－１０度補償膜ファラデー素子を組み合わせた時の電磁石磁界強度とファラデー回転角の関係を図５に、また電磁石磁界強度と減衰量特性の関係を図６に示す。ここで基本膜ファラデー素子は例えば$Tb_{1.00}Y_{0.65}Bi_{1.35}Fe_{4.05}Ga_{0.95}O_{12}$なる組成の磁性ガーネットＬＰＥ膜であり、補償膜ファラデー素子は例えば$Gd_{1.00}Y_{0.75}Bi_{1.25}Fe_{4.00}Ga_{1.00}O_{12}$なる組成の磁性ガーネットＬＰＥ膜である。このような組み合わせにすると、ファラデー回転角の可変幅が、－１０～９０度と大きくなり、最大減衰量も４０ｄＢ程度まで大きくできる。

【００２６】以上、本発明の一実施例について説明したが、本発明はかかる構成のみに限定されるものではない。基本膜ファラデー素子と補償膜ファラデー素子の挿入位置は、図１の例に限られるものではない。図７は、他の実施例を示している。説明を簡略化するために、図１と対応する光学部品については同一符号を付す。

【００２７】図７のＡに示す例では、基本膜ファラデー素子１４と補償膜ファラデー素子１６を、分離合成用複屈折素子１０とレンズ１２との間に配置している。図１＊の場合も同様であるが、基本膜ファラデー素子１４と補償膜ファラデー素子１６の順序は逆でもよい。図７のＢに示す例では、基本膜ファラデー素子１４をレンズ１２と反射鏡１８との間に、補償膜ファラデー素子１６を分離合成用複屈折素子１０とレンズ１２との間に配置している。図７のＣに示す例では、逆に、基本膜ファラデー素子１４を分離合成用複屈折素子１０とレンズ１２との間に、補償膜ファラデー素子１６をレンズ１２と反射鏡１８との間に配置している。

【００２８】基本膜ファラデー素子及び補償膜ファラデー素子が複数に及んだ場合でも、分離合成用複屈折素子１０と反射鏡１８との間であれば、どの位置に配置してもよい。例えば図７のＤに示す例では、２枚の基本膜ファラデー素子と１枚の補償膜ファラデー素子を、基本膜ファラデー素子１４、補償膜ファラデー素子１６、基本膜ファラデー素子１４の順に重ねて、レンズ１２と反射鏡１８との間に配置している。

【００２９】電磁石磁界強度０での挿入損失が１ｄＢ以下になる基本膜回転角と補償膜回転角の関係を調査した結果を表１に示す。また基本膜回転角が６１度以下の場合は補償膜回転角が－３度以下、基本膜回転角が６１度以上の場合は表１に示した範囲内であれば２５ｄＢ以上の高減衰量を得ることができる。

【００３０】

【表１】

基本膜最大回転角θ１（度）	補償膜最大回転角θ２（度）
４０	θ２≧－８
４２	θ２≧－１０
４４	θ２≧－１２
４６	θ２≧－１４
４８	θ２≧－１６
５０	θ２≧－１８
５２	θ２≧－２０
５４	θ２≧－２２
５６	θ２≧－２４
５８	θ２≧－２６
６０	θ２≧－２８
６１	－２９≦θ２≦－３
６２	－３０≦θ２≦－４
６４	－３２≦θ２≦－６
６６	－３４≦θ２≦－８
６８	－３６≦θ２≦－９
７０	－３８≦θ２≦－１１
７２	－４０≦θ２≦－１３
７４	－４２≦θ２≦－１５
７６	－４４≦θ２≦－１７
７８	－４６≦θ２≦－１９
８０	－４８≦θ２≦－２１
８２	－５０≦θ２≦－２３
８４	－５２≦θ２≦－２５
８６	－５４≦θ２≦－２７
８８	－５６≦θ２≦－２９
９０	－５８≦θ２≦－３１

【００３１】電磁石磁界強度０での挿入損失が小さく、且つ高減衰量を得ることができる基本膜ファラデー素子と補償膜ファラデー素子のファラデー回転角の関係を示したのが図８の斜線で示す領域である。数式で示すと、基本膜ファラデー素子による最大回転角をθ_1、補償膜ファラデー素子による最大回転角をθ_2としたとき、

$\theta_1 \leqq 61$度の場合、

$32-\theta_1 \leqq \theta_2 \leqq -3$

$\theta_1 \geqq 61$度の場合、

$32-\theta_1 \leqq \theta_2 \leqq 58-\theta_1$

なる関係を満たすようにすることが望ましい。

【００３２】具体的には、固定磁界印加手段は、軸方向に着磁した円環状の永久磁石を光軸上に配置することで構成し、可変磁界印加手段は、Ｃ型の磁心にコイルを巻

装した電磁石として、そのギャップ内に基本膜ファラデー素子が位置するような構成とする。本発明は反射型であり、反射鏡の裏面側には光路が存在しないので、その反射鏡の裏側のスペースを利用して電磁石を配置することで、平面的な部品配置が可能となり、可変光アッテネータの薄型化に有効である。

【００３３】

【発明の効果】本発明は上記のように構成した反射型の可変光アッテネータであるので、従来の対向型の光アッテネータと比較して、部品点数が少なく省スペースでありながら同等の性能を発現しうる。また本発明に係る可変光アッテネータは、入力ポートと出力ポートが同一方向となるため、実装の自由度が増し、薄型化にも適した構造が得られる。更に部品点数が少ないため、低価格で製造することが可能となる。

【００３４】また本発明では、光が往復で通過するためにファラデー素子の厚みを従来の対向型の場合に比し半減でき、その点でも低コスト化できる。更に、基本膜ファラデー素子と補償膜ファラデー素子とを組み合わせる構成とすると、ファラデー回転角の可変幅が大きくなり、最大減衰量を４０ｄＢ程度まで大きくでき、良好な特性が得られる。

【図面の簡単な説明】

【図１】本発明に係る可変光アッテネータの一実施例を示す光路説明図。

【図２】その各光学部品間での偏波状況の説明図。

【図３】４５度基本膜ファラデー素子のみを用いた時の電磁石磁界強度とファラデー回転角の関係を示すグラフ。

【図４】４５度基本膜ファラデー素子のみを用いた時の電磁石磁界強度と減衰特性の関係を示すグラフ。

【図５】５５度基本膜ファラデー素子と－１０度補償膜ファラデー素子を組み合わせた時の電磁石磁界強度とファラデー回転角の関係を示すグラフ。

【図６】５５度基本膜ファラデー素子と－１０度補償膜ファラデー素子を組み合わせた時の電磁石磁界強度と減衰特性の関係を示すグラフ。

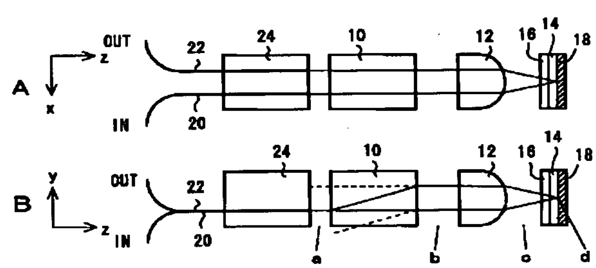
【図７】本発明に係る可変光アッテネータの他の実施例を示す光路説明図。

【図８】電磁石磁界強度０での挿入損失が小さく且つ高減衰量を得ることができる基本膜ファラデー素子と補償膜ファラデー素子のファラデー回転角の関係を示す説明図。

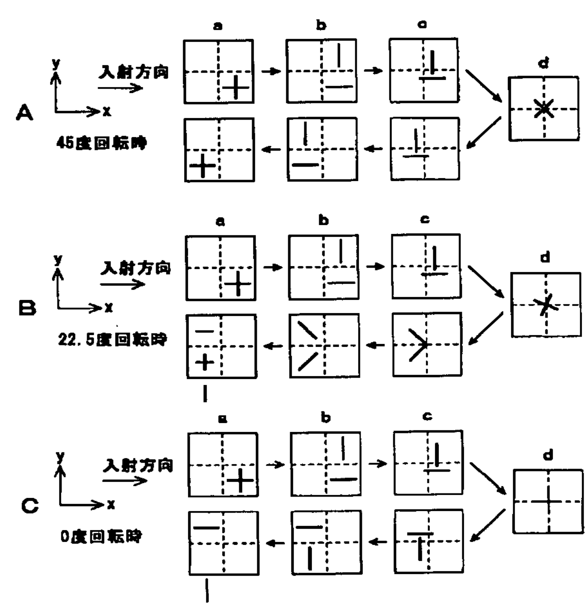
【符号の説明】

１０　分離合成用複屈折素子
１２　凸レンズ
１４　基本膜ファラデー素子
１６　補償膜ファラデー素子
１８　反射鏡
２０　入力ファイバ
２２　出力ファイバ
２４　２芯フェルール

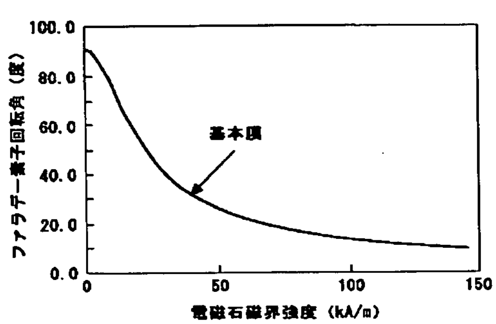
【図１】



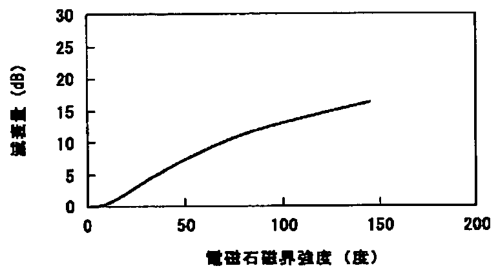
【図２】



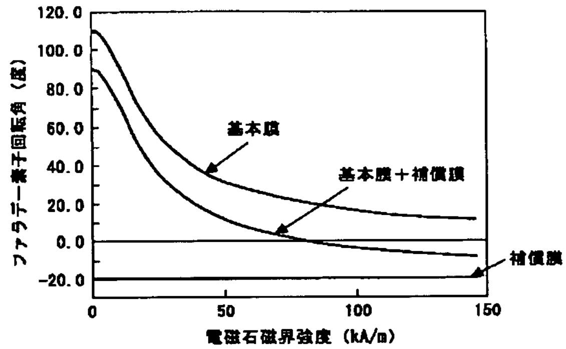
【図３】



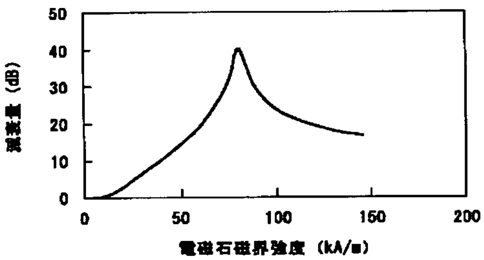
【図４】


減衰量 (dB)
電磁石磁界強度 (度)

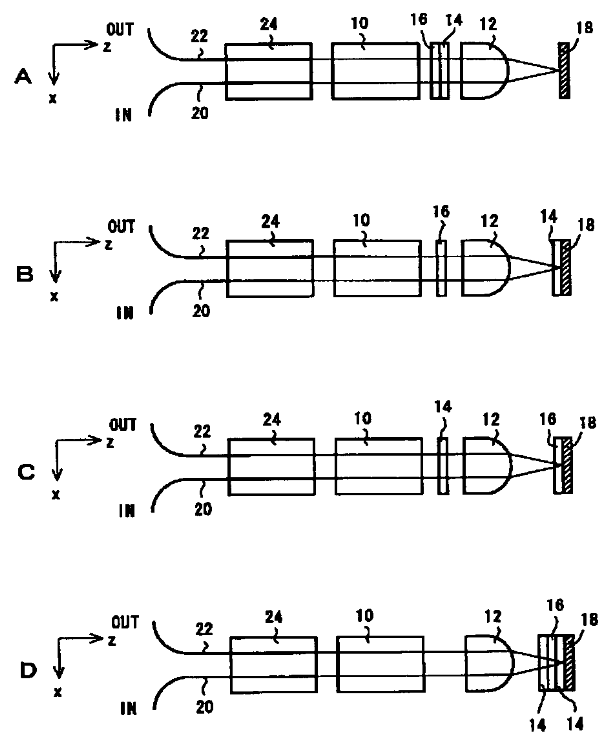
【図５】


ファラデー素子回転角 (度)
基本膜
基本膜＋補償膜
補償膜
電磁石磁界強度 (kA/m)

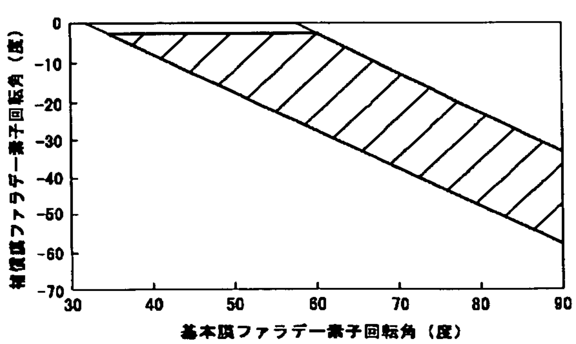
【図６】


減衰量 (dB)
電磁石磁界強度 (kA/m)

【図７】


A
B
C
D
OUT
IN
z
x

【図８】


補償膜ファラデー素子回転角 (度)
基本膜ファラデー素子回転角 (度)

フロントページの続き

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